Elements of Deep-Draft Navigation Projects

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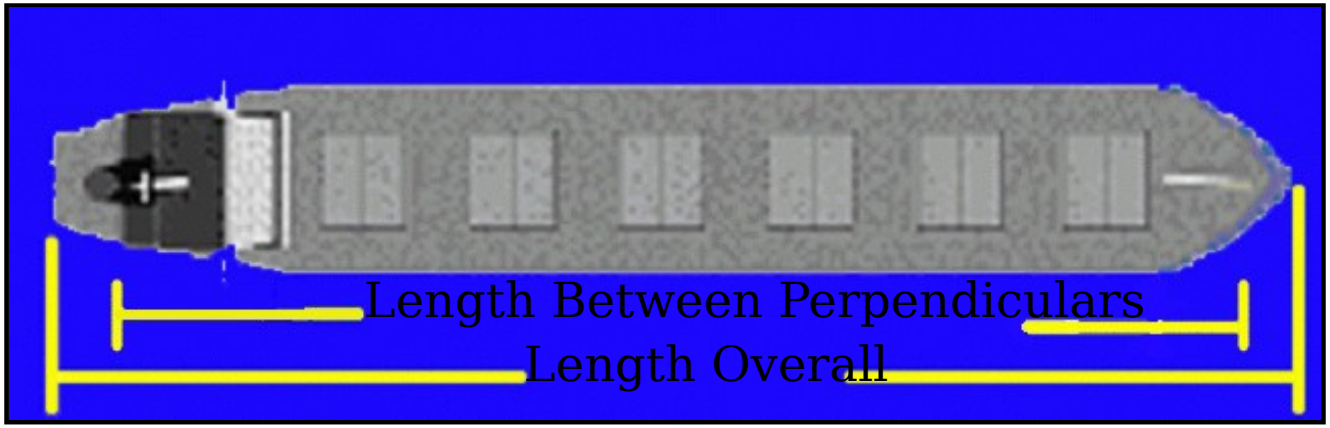
Basic Elements of Deep-Draft Navigation Projects

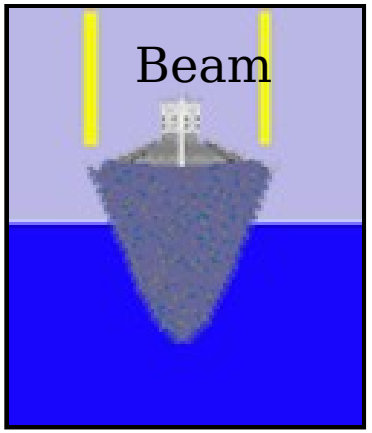
- Ships
  - Assist vessels
- Navigation Channels
- Environmental Conditions
- Structures
- Aids-to-Navigation
- Operational

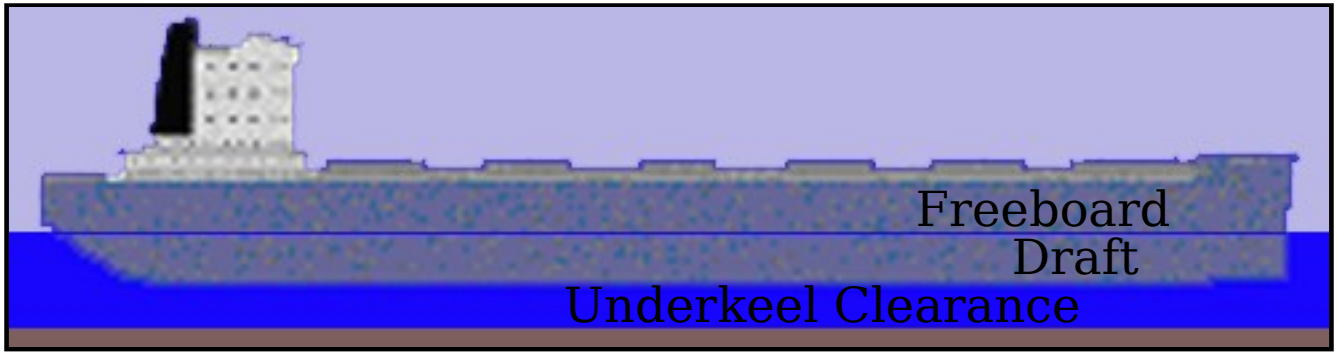
Typical Ships

- Container Ships
- Tankers
- Product or Bulk Carriers
- Car Carriers
- Cruise Ships

Ship Dimensions

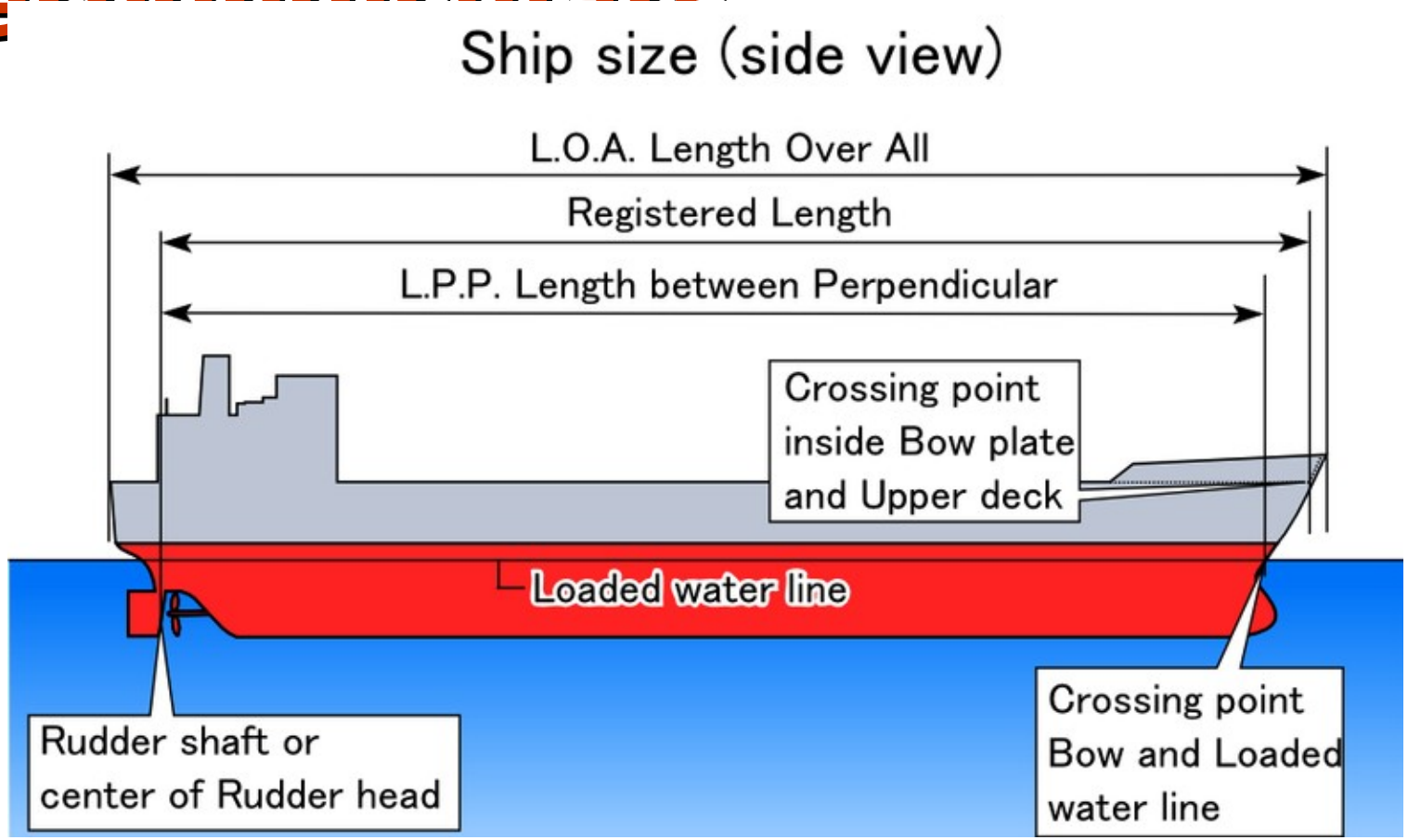






- **Length between perpendiculars (LBP)**
  - Governs cargo capacity and hydrodynamics
- **Trim:**
  - Difference in bow and stern draft.

Length between perpendiculars


Ship size (side view)
L.O.A. Length Over All
Registered Length
L.P.P. Length between Perpendicular
Crossing point inside Bow plate and Upper deck
Loaded water line
Rudder shaft or center of Rudder head
Crossing point Bow and Loaded water line

Ship Speeds

- **The faster the ship is traveling, the better the ship handles due to increased flow past the rudder.**
  - **Container ships 14 – 18 knots.**
  - **Tankers 10 – 12 knots.**
- **Problems associated with higher speeds.**
  - **Erosion.**
  - **Effects on moored vessels.**
  - **Effects on smaller craft.**

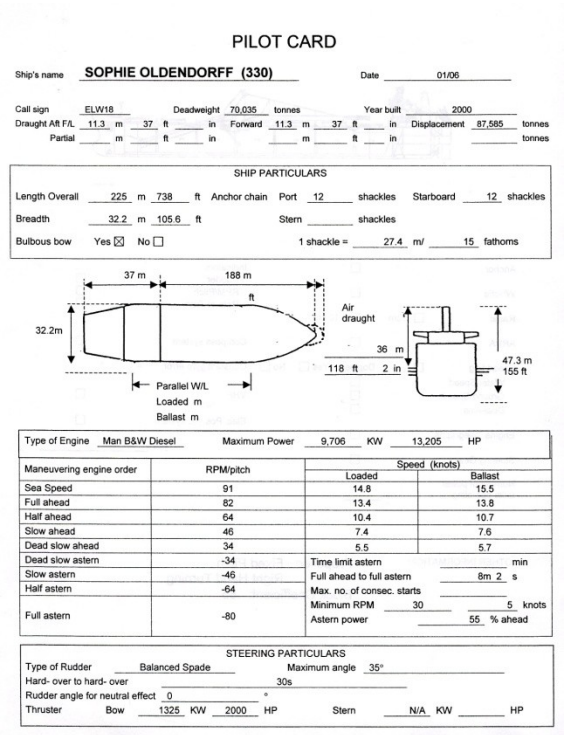
Ship Induced Erosion

Speed and Rudder Control

- Throttle typically has four ahead and four astern positions.
- Rudder commands are usually given in five degree increments.
- The most common rudder commands are 10 degrees, 20 degrees, and hard over.
- Sometimes course commands are given.

Pilot Cards

- **Ship Characteristics**



PILOT CARD

Ship's name SOPHIE OLDENDORFF (330) Date 01/06

Call sign ELW18 Deadweight 70,035 tonnes Year built 2000

Draught Aft F/L 11.3 m 37 ft in Forward 11.3 m 37 ft in Displacement 87,585 tonnes

Partial m ft in m ft in tonnes

SHIP PARTICULARS

Length Overall 225 m 738 ft Anchor chain Port 12 shackles Starboard 12 shackles

Breadth 32.2 m 105.6 ft Stern shackles

Bulbous bow Yes ☒ No ☐ 1 shackle = 27.4 m/ 15 fathoms

37 m 188 m ft

32.2m

Air draught

36 m

118 ft 2 in

47.3 m 155 ft

Parallel W/L

Loaded m

Ballast m

Type of Engine Man B&W Diesel Maximum Power 9,706 KW 13,205 HP

Maneuvering engine order	RPM/pitch	Speed (knots) Loaded	Ballast
Sea Speed	91	14.8	15.5
Full ahead	82	13.4	13.8
Half ahead	64	10.4	10.7
Slow ahead	46	7.4	7.6
Dead slow ahead	34	5.5	5.7
Dead slow astern	-34	Time limit astern	min
Slow astern	-46	Full ahead to full astern	8m 2 s
Half astern	-64	Max. no. of consec. starts	
Full astern	-80	Minimum RPM 30	5 knots
		Astern power	55 % ahead

STEERING PARTICULARS

Type of Rudder Balanced Spade Maximum angle 35°

Hard- over to hard- over 30s

Rudder angle for neutral effect 0 °

Thruster Bow 1325 KW 2000 HP Stern N/A KW HP

Maneuvering engine order	RPM/pitch	Speed (knots) Loaded	Ballast
Sea Speed	91	14.8	15.5
Full ahead	82	13.4	13.8
Half ahead	64	10.4	10.7
Slow ahead	46	7.4	7.6
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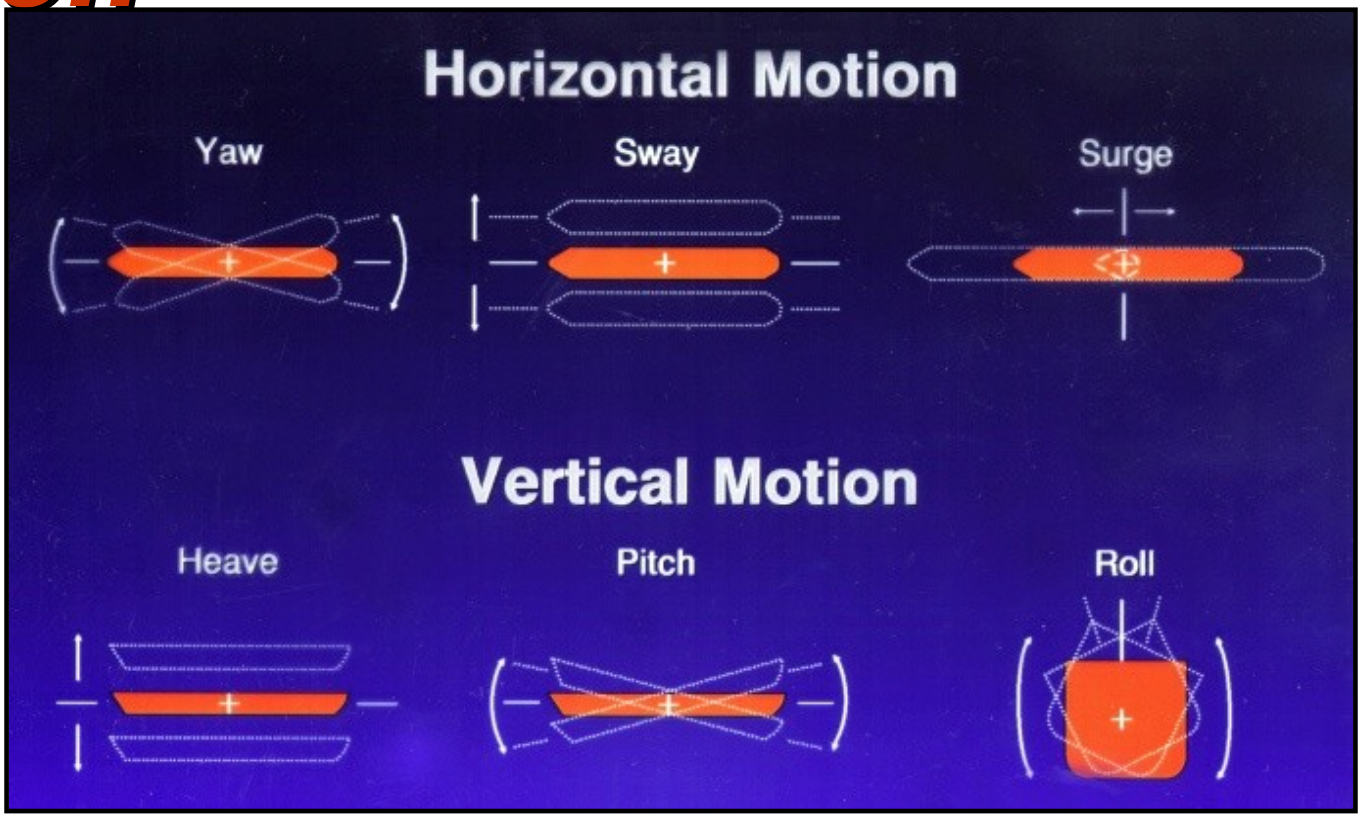
Six Degrees of Ship Motion

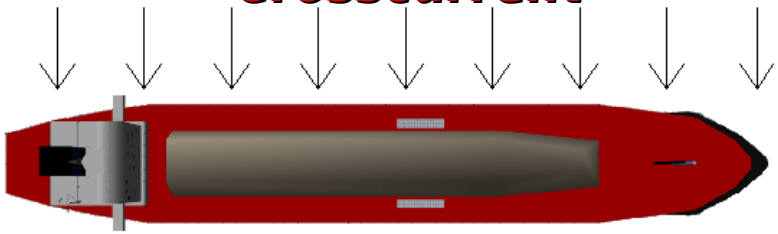


Ship Handling 101

- It's not like driving your car.

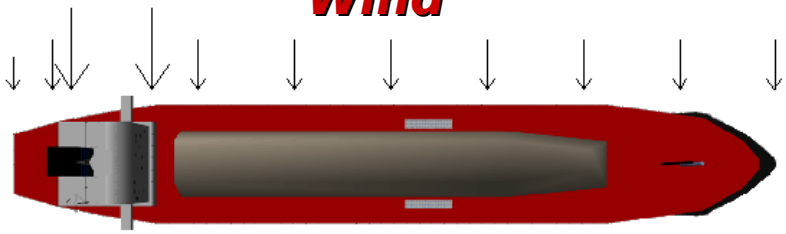
Examples of Forces Acting Upon Ships

Crosscurrent

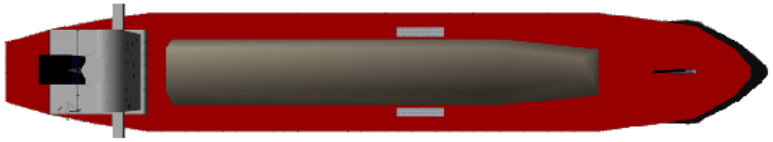


Rudder

Wind



Tugs/Thrusters

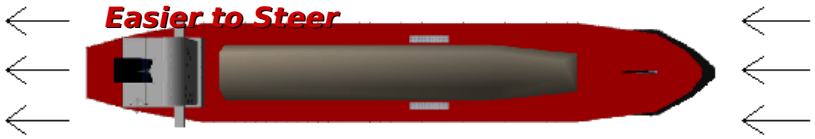


Fair Tide / Head Tide / Jetties

Head Tide

Slows Ship Down

Easier to Steer



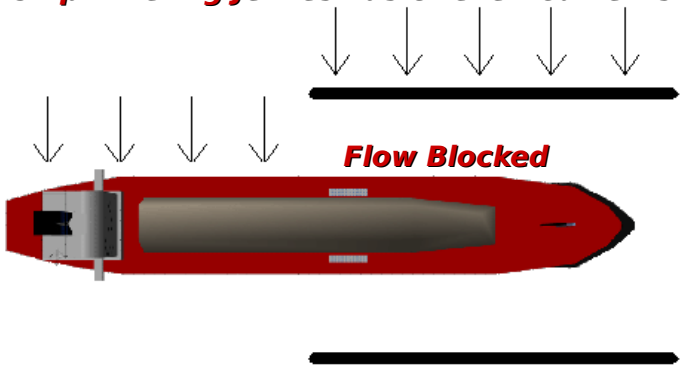
Fair Tide or Following Tide

Speeds Ship Up

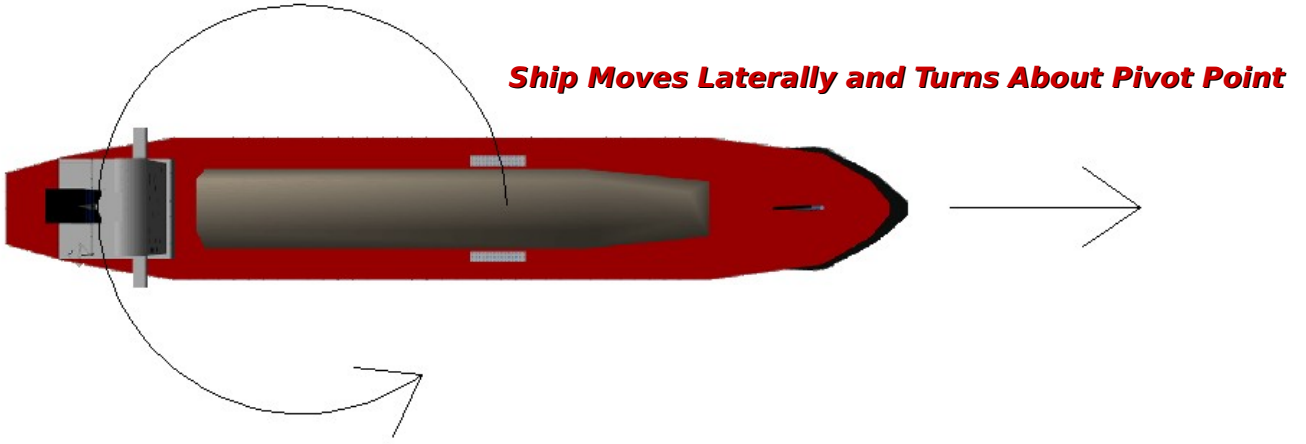
Harder to Steer

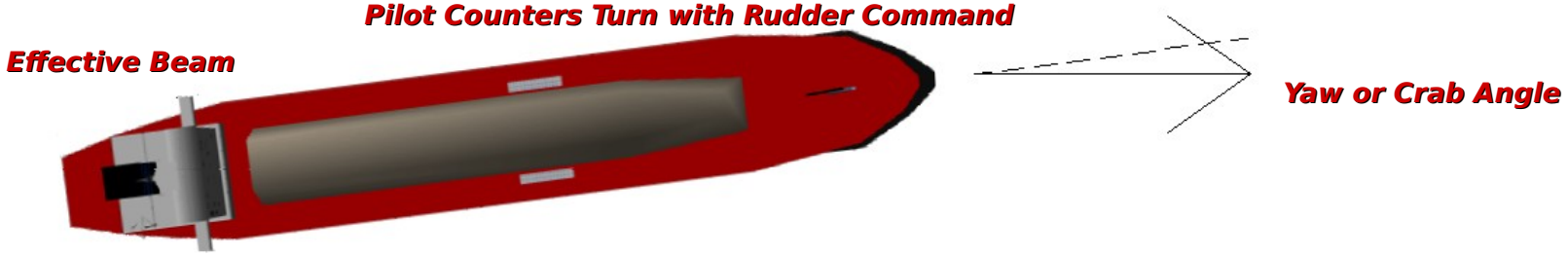
Sometimes use tugs to avoid going to fast

Ship Entering Jetties has Uneven Currents

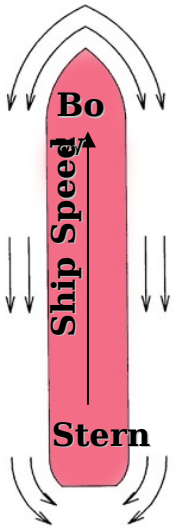


Summation of Forces and Moments

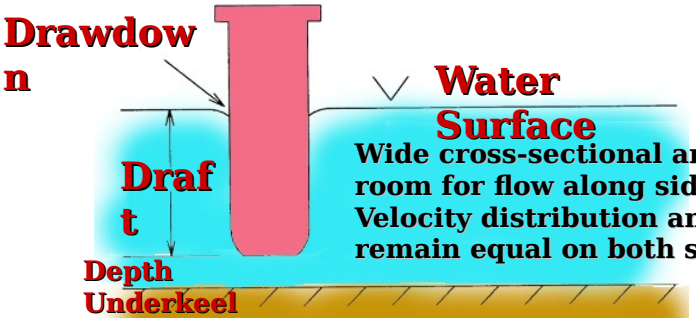




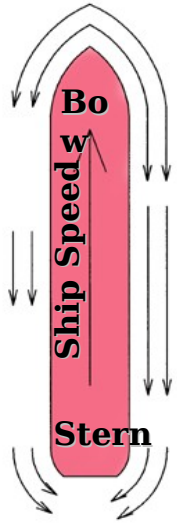
Flow Around Vessel in Open Water



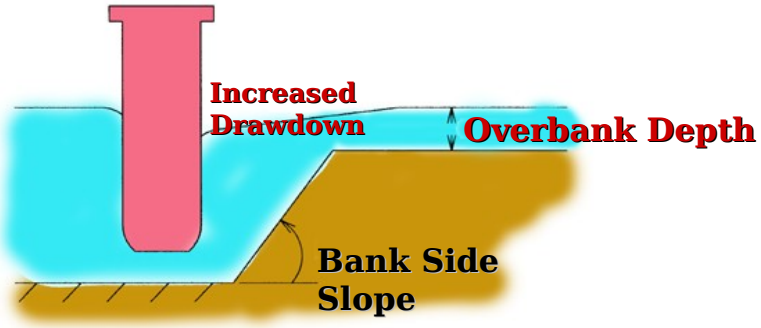
- Water is displaced by the ship's bow as the vessel moves through the waterway
- Displaced water moves alongside vessel, from bow to stern. Due to the requirement for conservation of energy, the water level drops along the side of the vessel. The drop in water level is in response to the velocity increase along side the ship. The water level drop is referred to as drawdown.
- Water fills void behind vessel.


Drawdown
Water Surface
Draft
Depth Underkeel
Wide cross-sectional area allows room for flow along side of ship. Velocity distribution and drawdown remain equal on both sides of vessel.

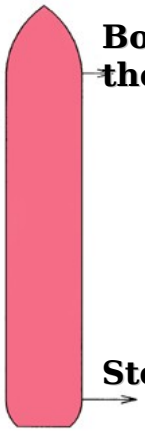
Flow Around Vessel Approaching Bank



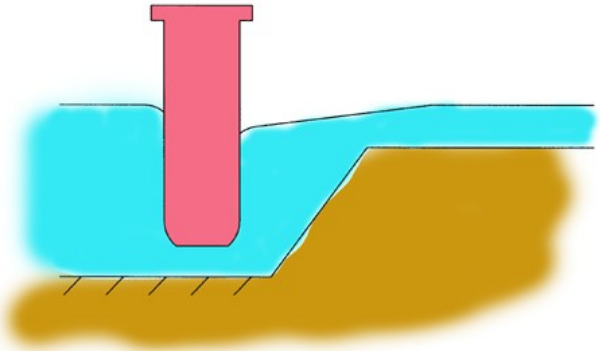
- The flow rate of water displaced from bow to stern is a function of the ship's speed through the water and the ship's size. Assuming the ship remains at a constant speed, the flow rate along side of the vessel remains constant.
- The flow rate along side the vessel is equal to the product of the water's velocity and the cross-sectional area of the flow. Therefore, as the ship nears the bank and the cross-sectional area decreases, the water velocity must increase on the side of the ship near the bank. Conservation of energy requires an additional drop in the water level (increased drawdown) as the velocity increases. The water velocity on the opposite side of the ship is not significantly affected by the near bank.
- The cross-sectional area available for flow alongside a ship is a function of the bank side slope, the overbank depth, and the ship's draft. A portion of the displaced flow can flow under the keel of a shallow drafted ship.



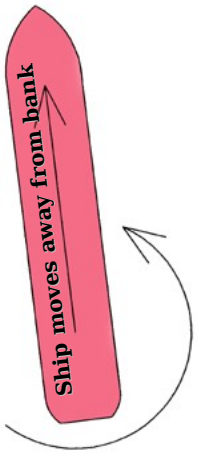
Vessel Moves Towards Bank



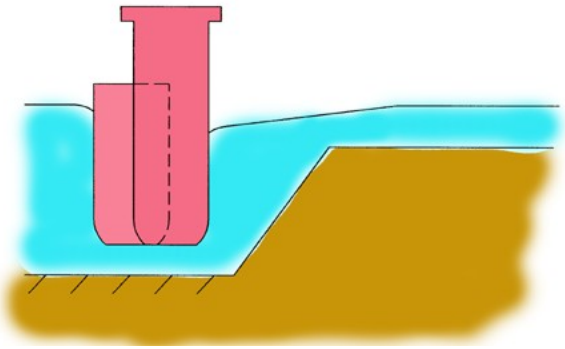
- The increased drawdown on the side of the ship near the bank causes the vessel to move towards the bank. The ship's stern moves towards the bank faster than the bow.



Vessel Turns Away From Bank



Ship Rotation



- The vessel rotates away from the bank because the ship is moving forward as the stern moves toward the bank faster than the bow.
- The cross-sectional area for flow becomes smaller at the stern than at the bow. This causes the velocities at the stern to increase, accelerating the ship's rotation away from the bank.

Ships

- Design Ship
  - Economically drives the project
- Special Considerations
  - Special safety issues due to size and/or cargo
    - LNG
- Two-way traffic
  - Determines channel width in many ports
- Shallow-draft
  - Tug and barge
- Other craft
  - Pleasure, ferries, commercial, etc.

Tanker/Bulk Carrier

- Carry product in hull
- Cargo capacity is dead-weight tons (dwt)
  - Also includes fuel, crew & supplies, etc
- Maximize volume of product
  - Will often wait for high water
  - Labor less expensive
- Strongly effected by current when loaded
- Strongly effected by wind when empty or in ballast
  - Can leave channel - sometimes

Container Ships

- **Carry product in containers**
  - Rated by Total Equivalent Units (TEU)
    - TEU is standard 20- x 8- x 8- ft box
- **Schedule Driven**
  - 24-hour dockside operations
    - Labor is very expensive
  - Transit during all hours of tidal cycle
- **Panamax**
  - Largest that can lock through Panama Canal
    - 965- x 106- x 39.5-ft
- **New Panamax**
  - Lock size
- **Post-Panamax**
- **Bow & stern thrusters**

New Panamax

	Locks	Panamax	New locks	New Panamax[1]
Length	1,050 ft (320.04 m)	965 ft (294.13 m)	1,400 ft (427 m)	1,200 ft (366 m)
Width	110 ft (33.53 m)	106 ft (32.31 m)	180.5 ft (55 m)	160.7 ft (49 m)
Depth, draft[2]	41.2 ft (12.56 m)	39.5 ft (12.04 m)	60 ft (18.3 m)	49.9 ft (15.2 m)
TEU		5000		12000

[1] New Panamax sizes are published in metric system[1]

[2] Draft in Tropical Freshwater (TF)

Cruise Ships

- **High freeboard**
  - Influenced by wind.
  - Possible vertical clearance problems.
- **Usually draft about 27 ft.**
- **Schedule driven**

Car Carriers

- High Freeboard, similar to container ships.
- Bridge is close to bow.

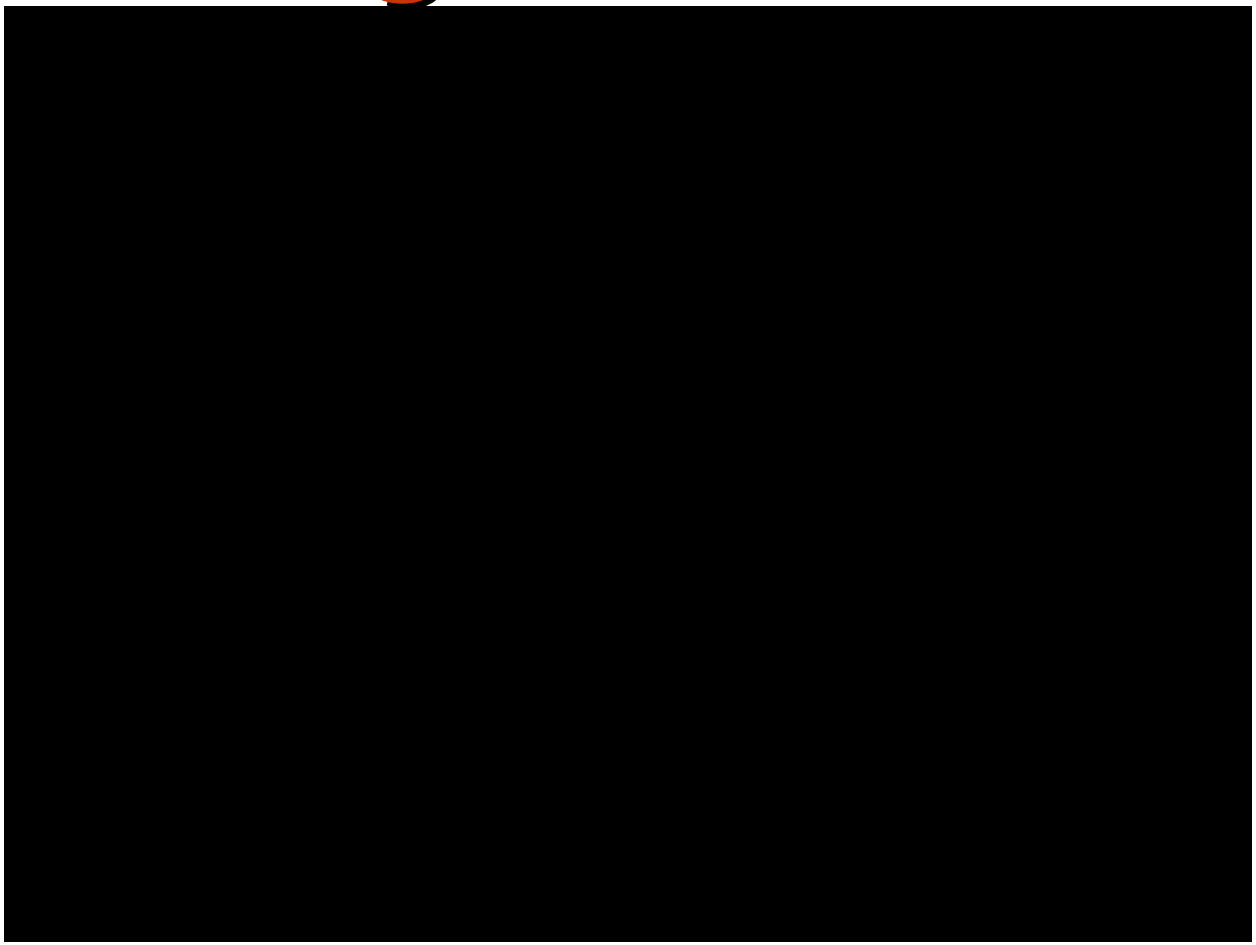
Tugs

- **Provide assistance**
  - Stopping
  - Turning
  - Controlling speed
  - Required escort through environmentally sensitive areas.

Tug Types

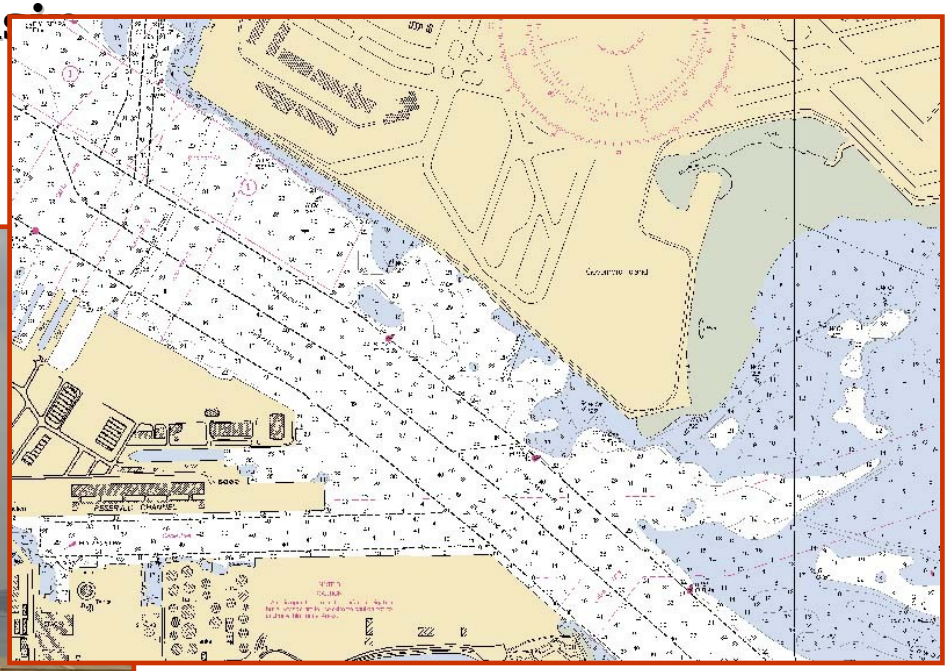
- **Conventional**
  - Generally ineffective at ship speeds greater than four knots.
- **Tractor**
  - Voith Schneider
  - Azimuthing Drive
  - Useful at higher ship speeds
  - Indirect mode.

Tractor Tugs



Air Traffic Issues

- Approach to Logan Airport required re-design of Boston Harbor Turning Basin

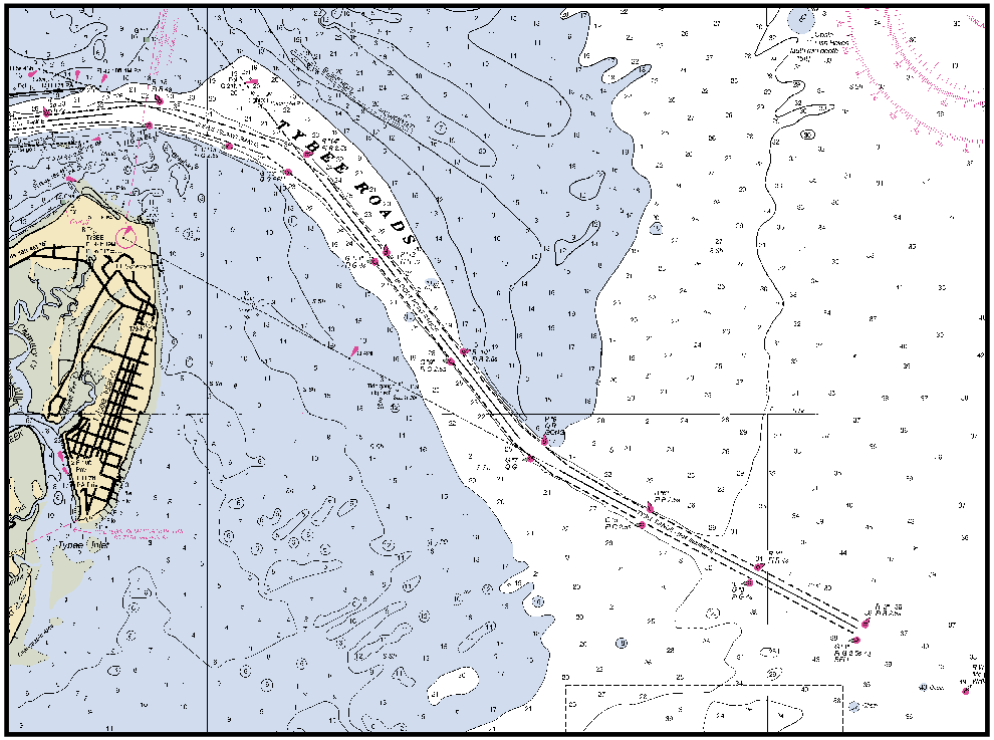


Navigation Channels

- Entrance Channels
- Interior Channels
- Turning Basins
- Anchorages

Entrance Channels

- Connects the harbor to the ocean, gulf, or lake.
- Often requires extra depth due to wave conditions.
- Deepening of Savannah Entrance Channel will require reroute.

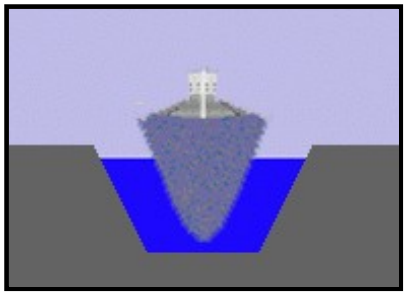


Interior Channels

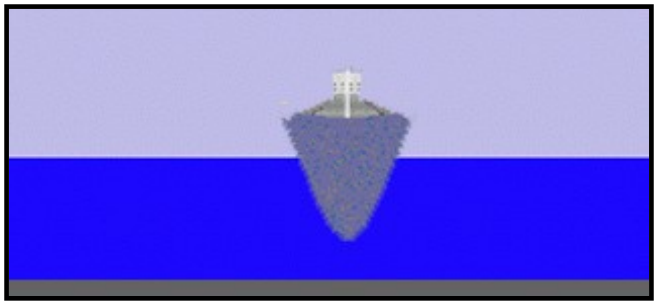
- Provide access to the various harbor facilities.
- Can be one-way or two-way channels.
- Typically a series of straight channel segments.
  - Bend wideners ease turn between segments.

Channel Cross Sections

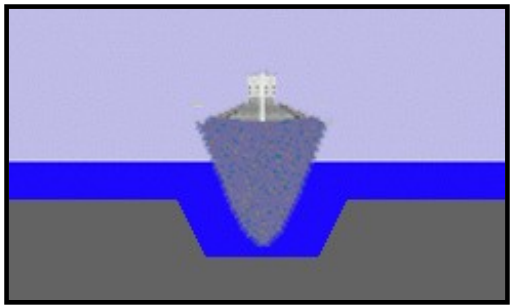
Canal



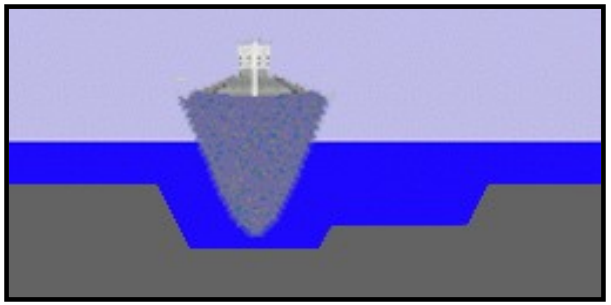
Shallow water



Trench



Asymmetric



One-Way or Two-Way Channels

- Two-way requirements based up amount of vessel traffic.
- Many two-way channels have restriction on beam combinations.
- Some ships, such as LNGs are one-way transits only.

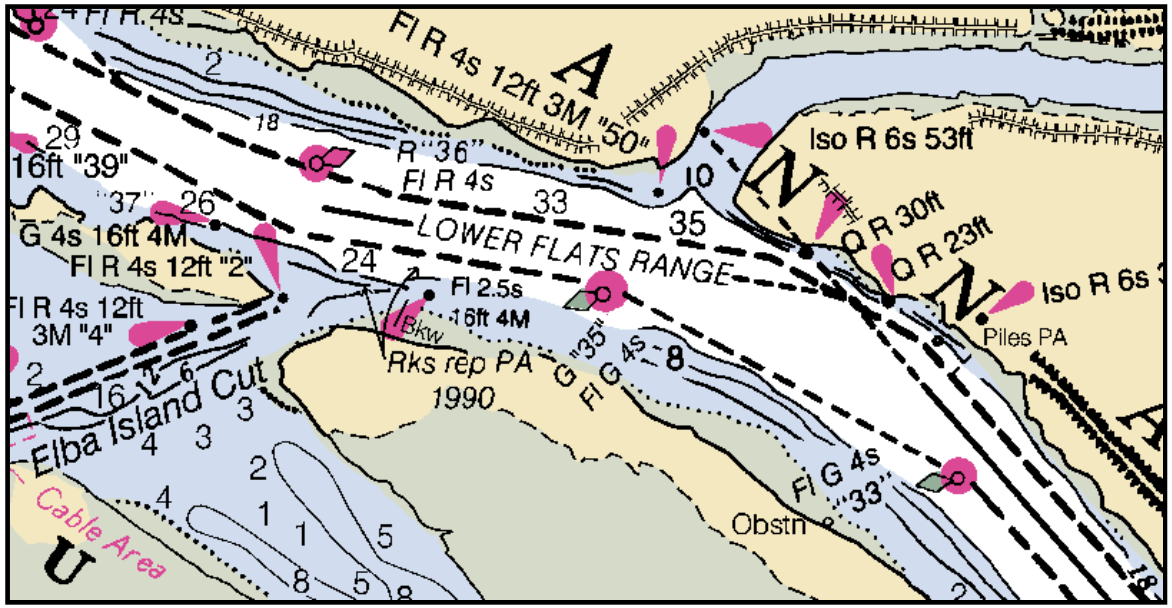
Passing Lanes

- **Additional width for two-way traffic in what basically is a one-way navigation system.**
  - **Meetings must be timed correctly**
  - **Lanes must be long enough for pilots to have confidence in their ability to time meetings**
  - **Sometimes system may be two-way, but passing lane allows larger ships to meet.**

- **Overtaking areas allow a faster moving ship to pass a slower moving vessel heading in the same direction. Usually requires more width than passing lanes.**

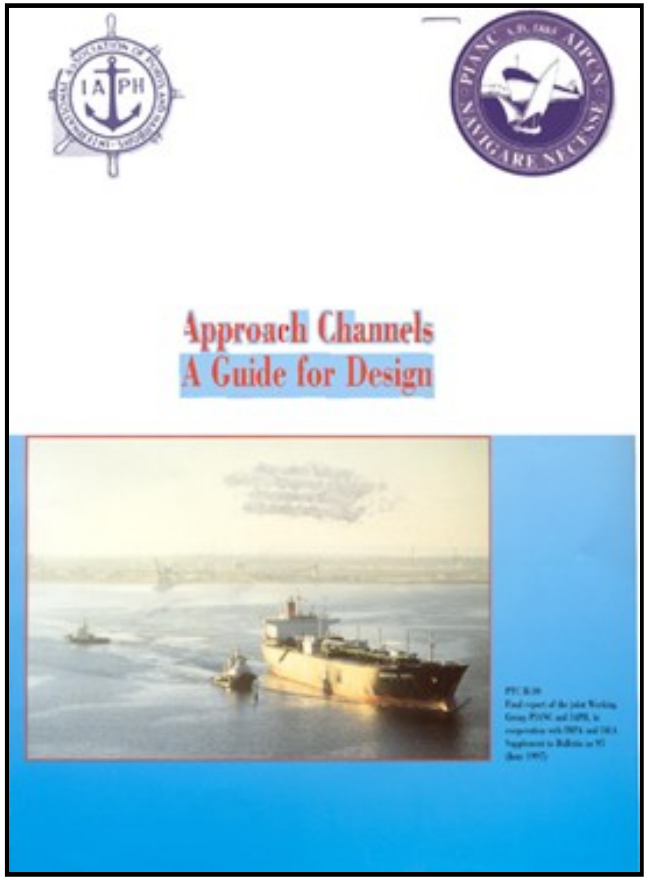
Straight Channel Segments

- **Connected by bend wideners.**



Channel Width Design Criteria

- **COE EM 1110-2-1613**
- **PIANC**
  - **Approach Channels**



Channel Width Design Criteria

(one-way channels)

Channel Cross Section	Design Ship Beam Multipliers for Maximum Current, Knots		
	0.0 to 0.5	0.5 to 1.5	1.5 to 3.0
Constant			
Shallow	3.0	4.0	5.0
Canal	2.5	3.0	3.5
Trench	2.75	3.25	4.0
Variable			
Shallow	3.5	4.5	5.5
Canal	3.0	3.5	4.0
Trench	3.5	4.0	5.0

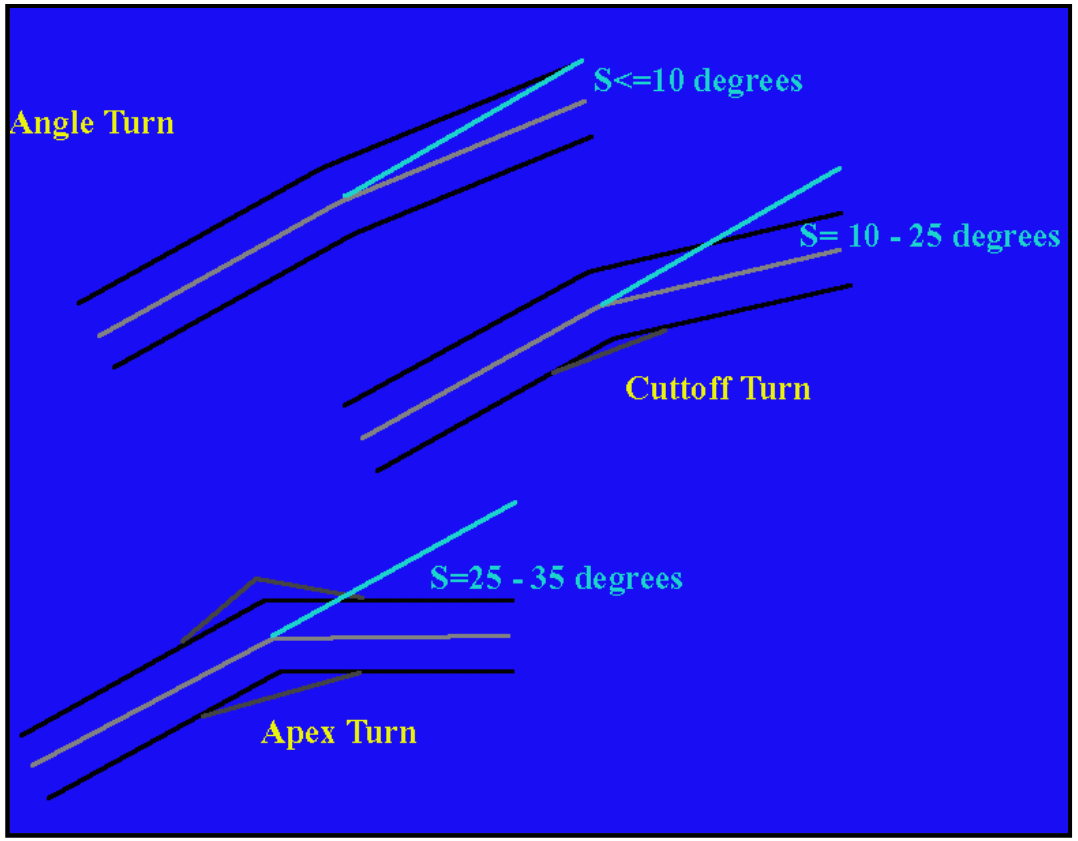
Channel Width Design Criteria

(two-way channels)

Channel Cross Section	Design Ship Beam Multipliers for Maximum Current, Knots		
	0.0 to 0.5 (0.0 o 0.8)	0.5 to 1.5 (0.8 to 2.5)	1.5 to 3.0 (2.5 to 5.0)
Uniform			
Shallow	5.0	6.0	8.0
Canal	4.0	4.5	5.5
Trench	4.5	5.5	6.5

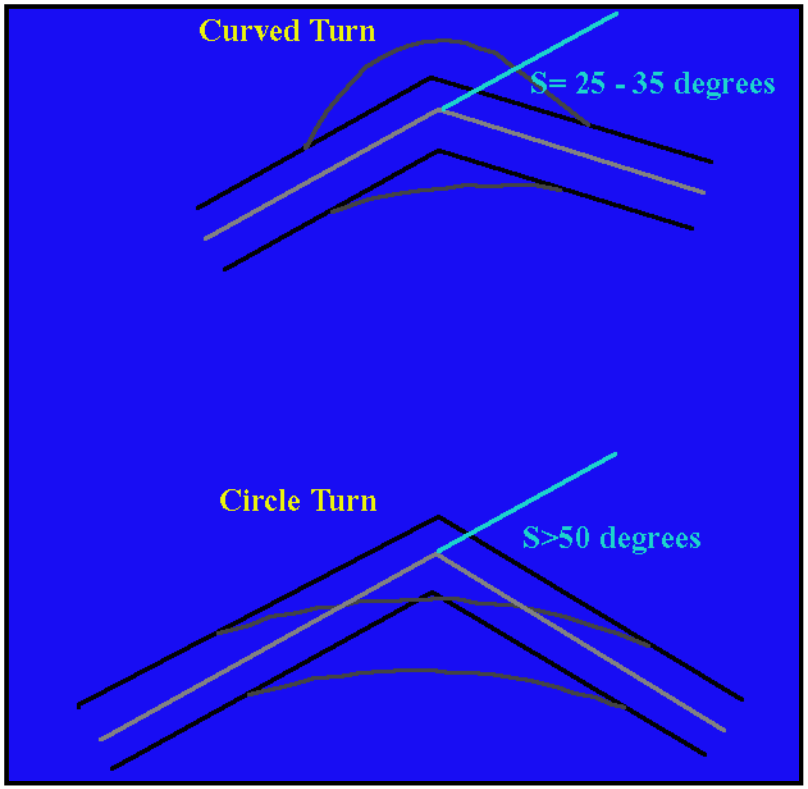
Straight Segment Bend Wideners

- Width increase and radius given in EM.



Curved Segment Bend Wideners

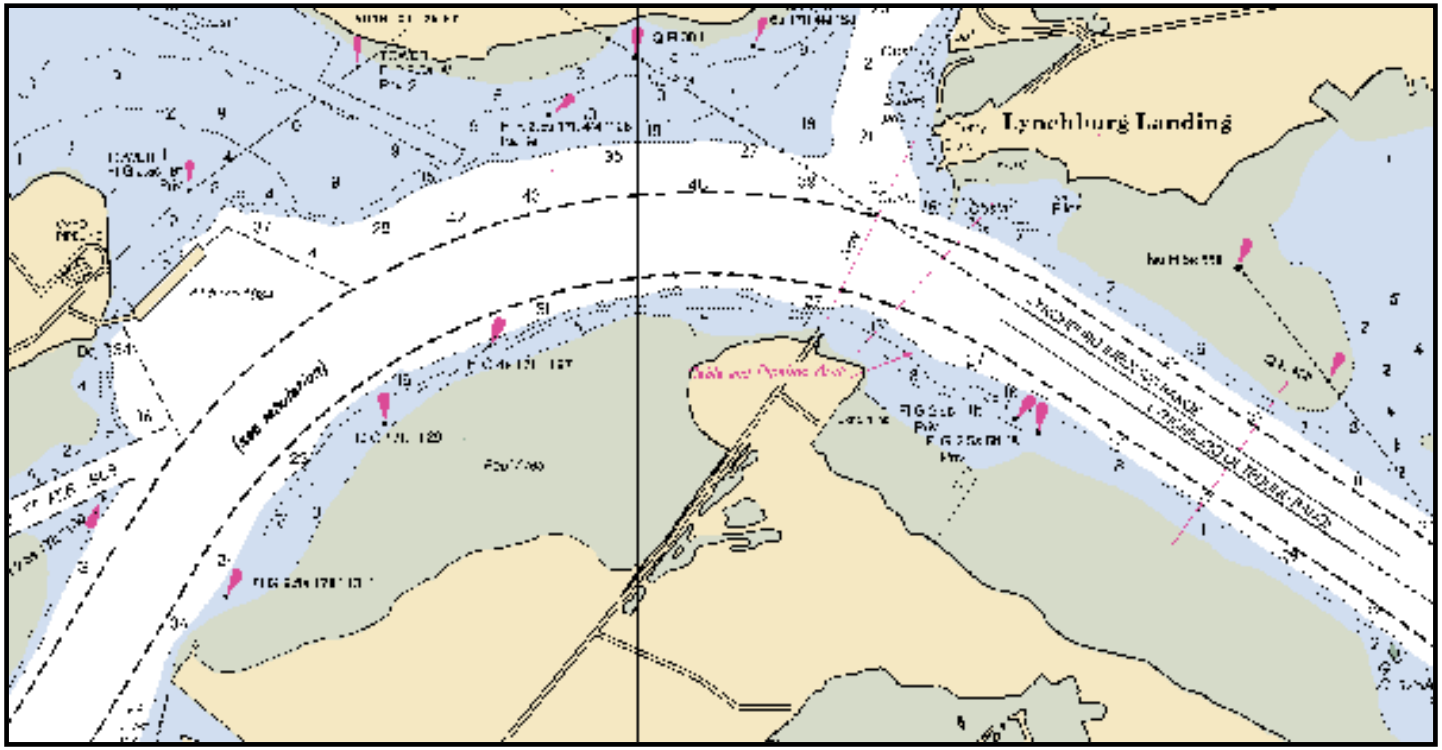
- Width increase and radius given in EM.



Curved Channel Segments

- Uncommon, but used to fit natural channel geometry.
- Effective in Houston Ship Channel. Pilots use bank-effects to make turns.

Lynchburg Turn - Houston Ship Channel

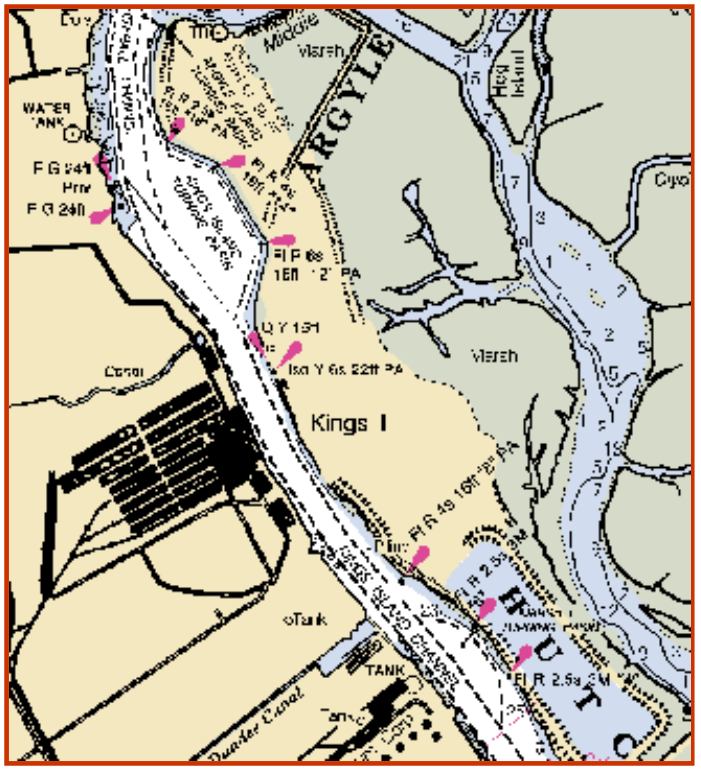


Turning Basins

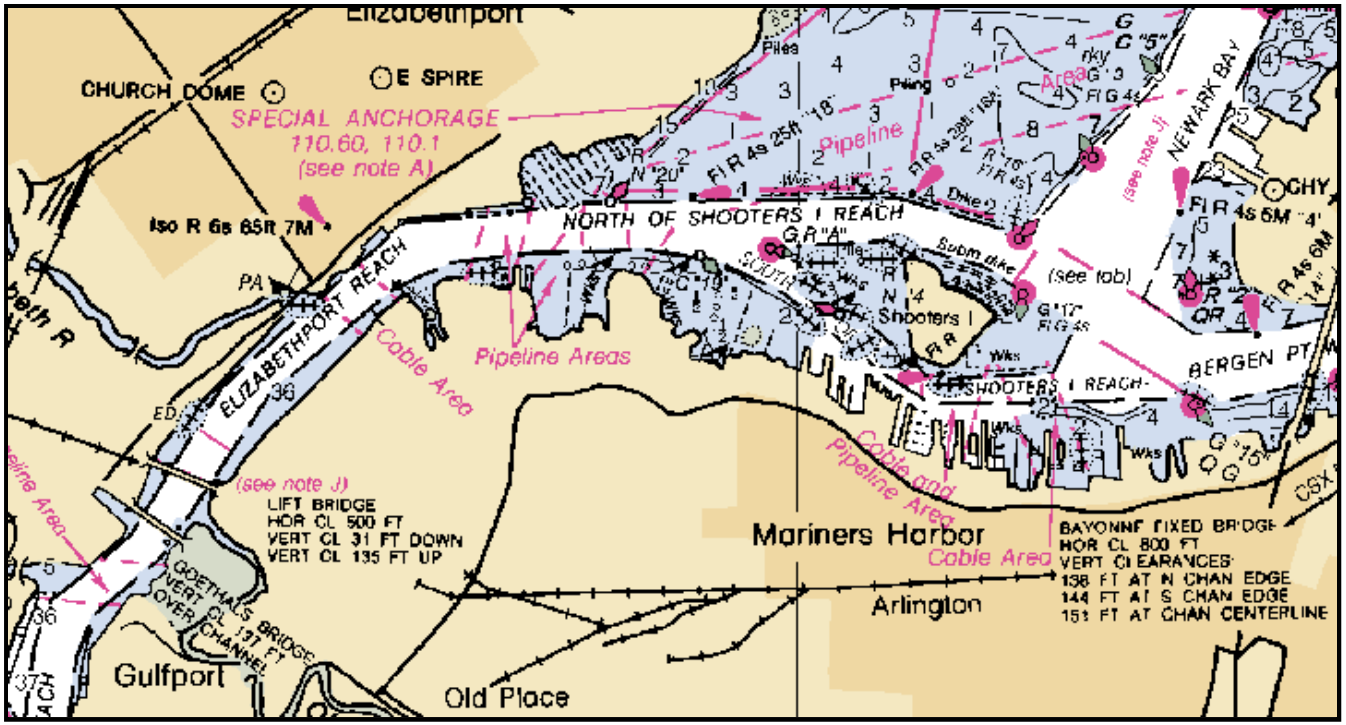
- Provide area to turn ship
- If turning basins are not always provided
  - Loop system
  - Backing required
- Size based upon turning circle in still water.
- Size based upon ellipse in moving water.

Typical Turning Basin

- Ships pass berthing areas inbound, turn and dock bow out. This allows ship to leave port quickly in case of emergency.
- Loading requirements may force vessel to dock bow in.
- Basin size limitations may require turning ship after unloading.



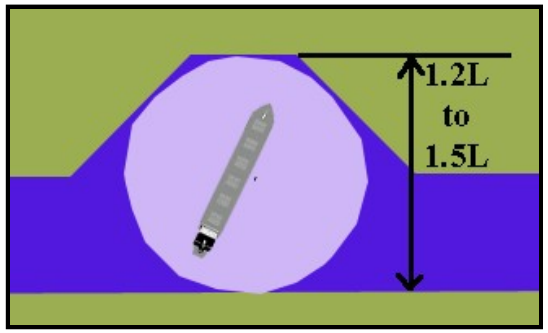
No Turning Basin Requires Backing Ship



Turning Basin Design

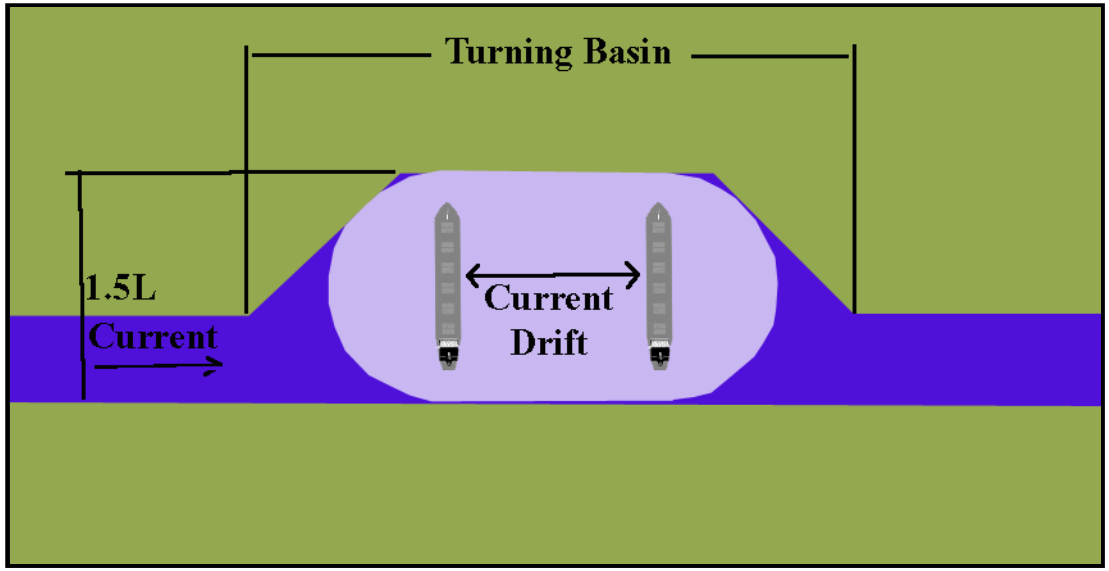
- **Preliminary design a factor of ship length (L) and current speed.**

Current Speed (knots)	Turning Basin Multiplier
0 < 1/2	1.2
½ < 1 1/2	1.5
> 1 ½	Simulator Design



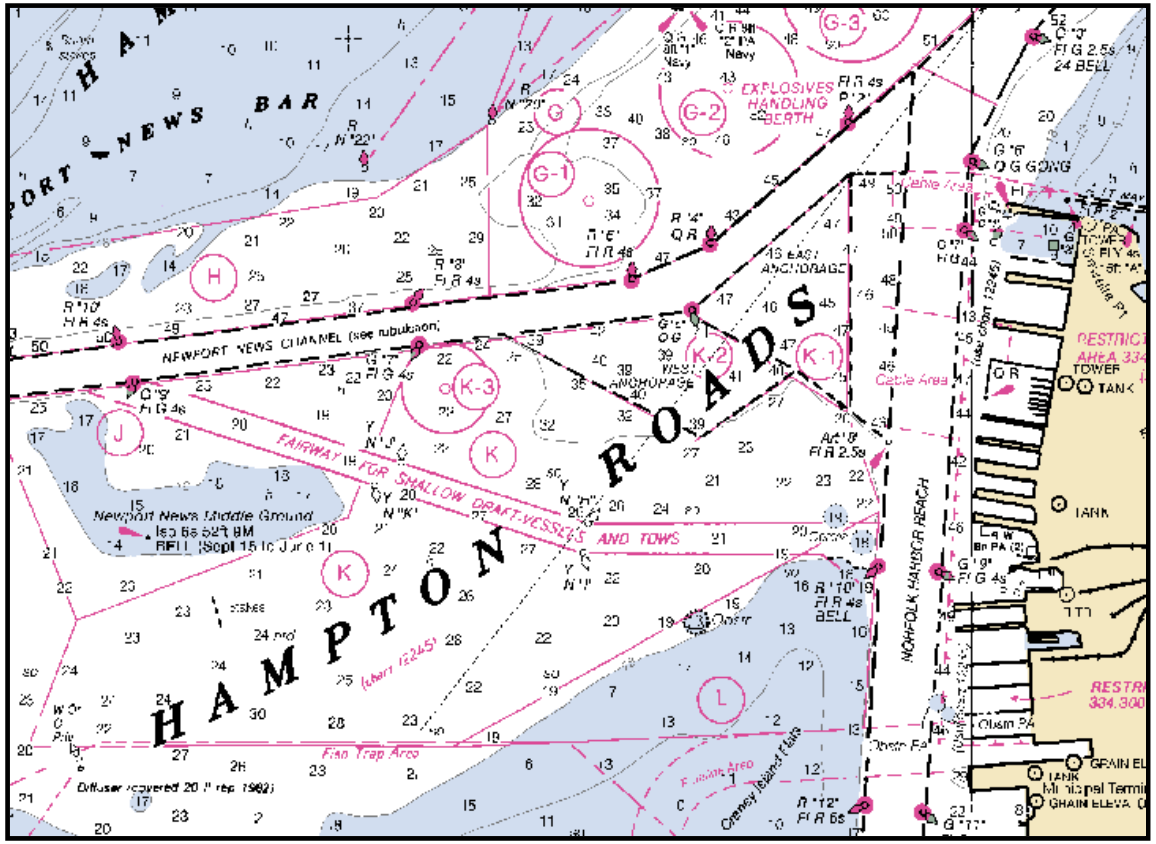
Turning Basin Design

- **Turning basins in areas of high current are elliptical.**
  - **Length design in ship simulation.**



Anchorage

- **Protected waiting area for ships.**



Environmental Conditions

- **Current**
  - **Tidal flow**
    - **Cross-currents cause most difficulty**
    - **Fresh-water inflow**
    - **Channel depth referenced to a vertical datum such as mean-lower-low-water.**
  - **River flow**
    - **Non-reversing**
    - **Channel depth is stage dependent.**
- **Wind**
- **Waves**
- **Ice**
- **Side-slope angle and overbank depth.**
- **Shoaling**

Elements of Deep-Draft Navigation Projects

Structures

- Jetties
- Breakwaters
- Dikes
- Bridges
- Docks

Elements of Deep-Draft Navigation Projects

Jetties

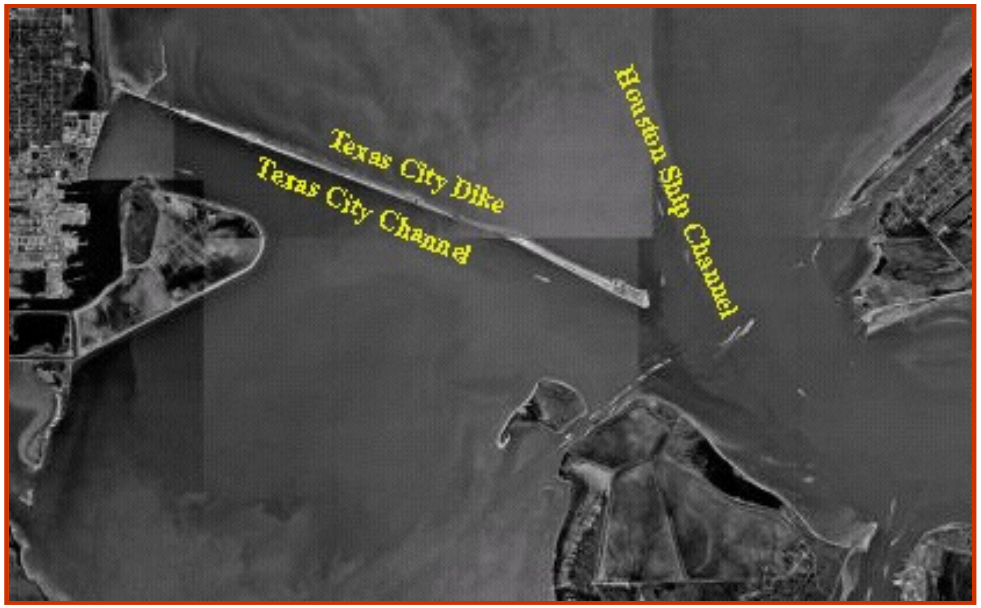
- Provide obstruction to littoral drift.
- Control entrance currents.
- Protection from waves.
- Reduce shoaling.

Breakwaters

- Breakwaters are structures placed offshore to dissipate the energy of incoming waves

Dikes

- Provide protection from currents
- Control currents to maintain navigable depth.
- Can be submerged.



Bridges

- Designed by state Department of Transportation
- Permitted by USCG
- Can be limiting factor for ship traffic, both horizontally and vertically

Baytown Bridge

Aids-to-Navigation (ATONS)

- **Installed and maintained by the United States Coast Guard.**
- **Two basic types**
  - **Channel markers**
  - **Range markers**

ATONS shown on chart

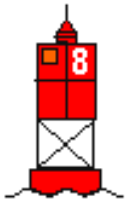
Port Side Lateral System
As seen entering from seaward
(Green Light Only
Odd Numbered Aids)

Starboard Lateral System
As seen entering from seaward
(Red Light Only
Even Numbered Aids)

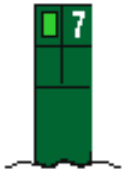
Green Light
Chart Symbol
"1"
Fl G 6s

Red Light
Chart Symbol
"2"
Fl R 6s

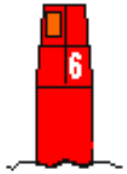
Green Lighted Buoy
Chart Symbol
G "9"
Fl G 4s



Red Lighted Buoy
Chart Symbol
R "8"
Fl R 4s



Can
Chart Symbol
G
C "7"



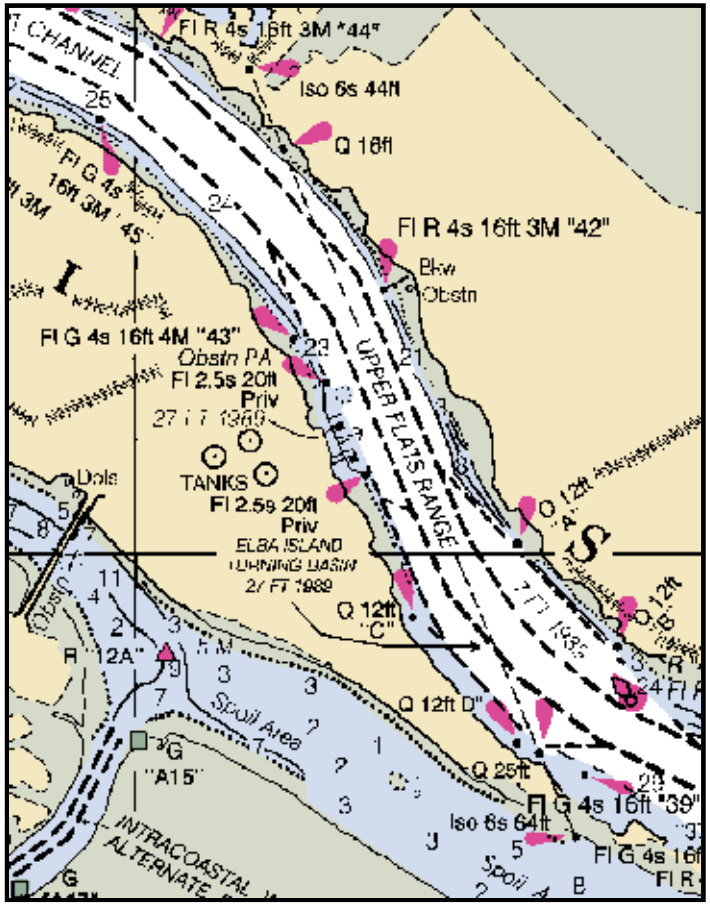
Nun
Chart Symbol
R
N "6"

Daymark
Chart Symbol
G
"1"

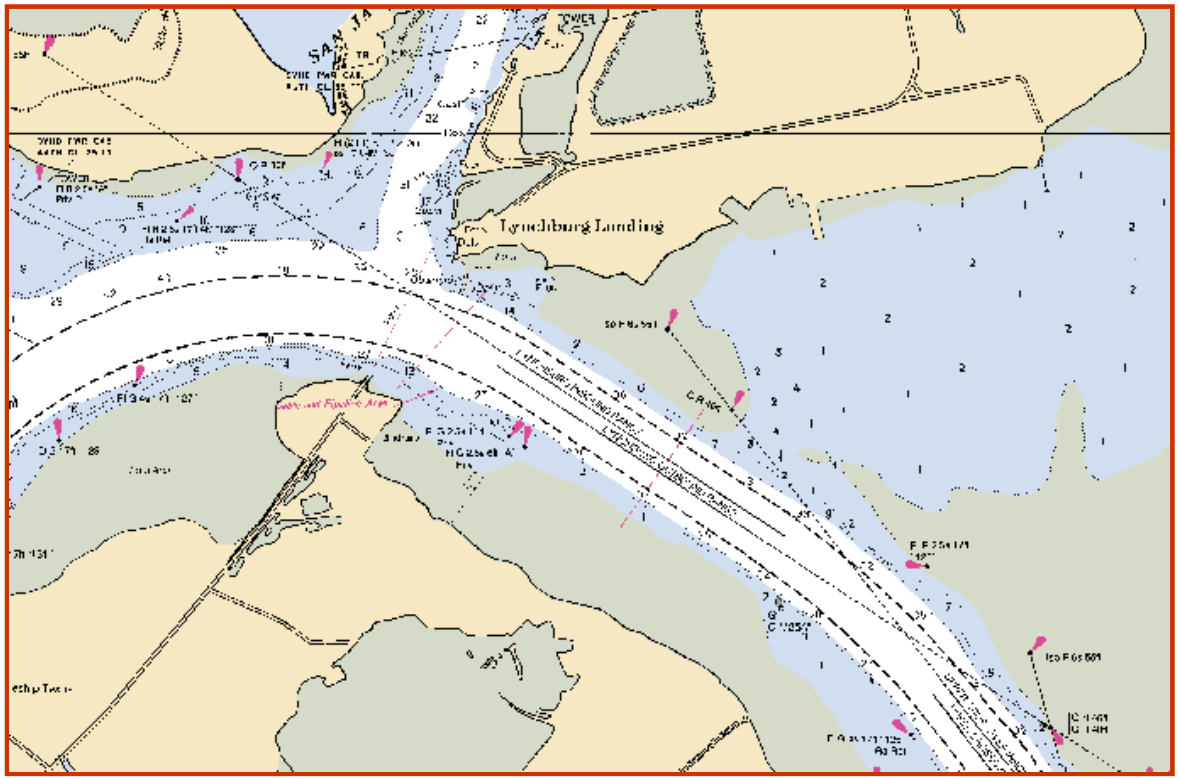
Daymark
Chart Symbol
R
"2"

Range Markers

- Two ranges are used to mark a straight line on the channel.
- Centerline ranges are most common.
- Offset ranges can be used for two-way traffic.



Offset Ranges



View of ranges from bridge

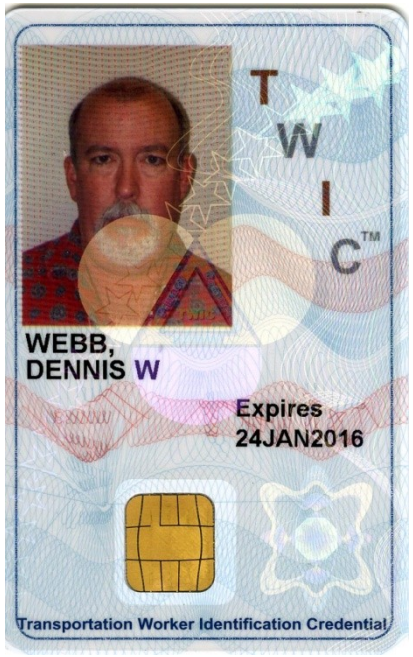
Channel Markers

- Mark edge of navigable waterway.
- Remember! *Red right returning*.
- Can be fixed when water is shallow enough for installation.
- Buoys float and are on chains so their position changes.
  - Watch circle
- Markers can interfere with shallow draft vessels that aren't restricted to navigation channel.

Harbor Pilots

- State licensed pilots required for foreign flag vessels.
- Federal pilots can handle coast-wise trade.
- Pilots are licensed for port and class of vessels.
- Some ports use “docking masters” when under tug assist.

Transportation Worker Identification Credential - TWIC



Shallow-Draft Vessels in Deep-Draft Channels

- Ship traffic often shares waterway with smaller craft.

Nautical Terms

- Above board - On or above the deck, in plain view, not hiding anything.
- Abeam - 'On the beam', a relative bearing at right angles to the centerline of the ship's keel.
- Aboard - On or in a vessel. - Close aboard means near a ship.
- Aft - Towards the stern (of the vessel)
- Aid to Navigation - (ATON) Any device external to a vessel or aircraft specifically intended to assist navigators in determining their position or safe course, or to warn them of dangers or obstructions to navigation.
- Astern - Toward the stern; an object or vessel that is abaft another vessel or object.
- Bar - Large mass of sand or earth, formed by the surge of the sea. They are mostly found at the entrances of great rivers or havens, and often render navigation extremely dangerous, but confer tranquility once inside. Berth - A bed on a boat, or a space in a port or harbor where a vessel can be tied up.
- Devil seam - The curved seam in the deck planking closest to the side of the ship, next to the scuppers. A sailor slipping on the deck would be "between the Devil and the deep blue sea".

Nautical Terms

- **Dressing down - Treating old sails with oil or wax to renew them, or a verbal reprimand.**
- **Fathom - A unit of length equal to 6 feet, roughly measured as the distance between a man's outstretched hands.**
- **Fill Your Hands – The method of boarding the ship safely from the pilot boat. Never release your grip on one until you have a firm grip on the other.**
- **First Mate - The Second in command of a ship.**
- **Fore - Towards the bow (of the vessel).**
- **Freeboard - The height of a ship's hull (excluding superstructure) above the waterline. The vertical distance from the current waterline to the lowest point on the highest continuous watertight deck. This usually varies from one part to another.**
- **Galley - the kitchen of the ship.**
- **Hawse-hole - A hole in a ship's bow for a cable, such as for an anchor, to pass through.**
- **Head - Bathroom.**
- **Hull - the shell and framework of the basic flotation-oriented part of a ship.**

Nautical Terms

- In the offing - In the water visible from on board a ship, now used to mean something imminent.
- Keel - the central structural basis of the hull.
- Land lubber - A person unfamiliar with being on the sea.
- Lee side - The side of a ship sheltered from the wind (cf. weather side).
- Line - the correct nautical term for the majority of the cordage or "ropes" used on a vessel. A line will always have a more specific name, such as mizzen topsail halyard, which describes its use.
- Loaded to the gunwales - Literally, having cargo loaded as high as the ship's rail; also means extremely drunk.
- Master - Either the commander of commercial vessel, or a senior officer of a naval sailing ship in charge of routine seamanship and navigation but not in command during combat.
- Mess - An eating place aboard ship. A group of crew who live and feed together.
- Navigation rules - Rules of the Road provides guidance on how to avoid collision and also used to assign blame when a collision does occur.
- Old man – The ship’s captain.

Nautical Terms

- **Part brass rags - Fall out with a friend. From the days when cleaning materials were shared between sailors.**
- **Pilot - Navigator. A specially knowledgeable person qualified to navigate a vessel through difficult waters, e.g. harbor pilot etc.**
- **Port - Towards the left-hand side of the ship facing forward (formerly Larboard). Denoted with a red light at night.**
- **Pusser - Purser, the one who buys, stores and sells all stores on board RN ships, including victuals, rum and tobacco. originally a private merchant, latterly a warrant officer.**
- **Radar - An electronic system designed to transmit radio signals and receive reflected images of those signals from a "target" in order to determine the bearing and distance to the "target".**
- **Range lights - Two lights associated to form a range (a line formed by the extension of a line connecting two charted points) which often, but not necessarily, indicates the channel centerline. The front range light is the lower of the two, and nearer to the mariner using the range. The rear light is higher and further from the mariner.**
- **Roll - A vessel's motion rotating from side to side, about the fore-aft axis. List (qv) is a lasting tilt in the roll direction.**
- **Scud - A name given by sailors to the lowest clouds, which are mostly observed in squally weather.**
- **Scuttlebutt - A barrel with a hole in used to hold water that sailors would drink from. Also: gossip.**

Nautical Terms

- Starboard - Towards the right-hand side of a vessel facing forward. Denoted with a green light at night.
- Square meal - A sufficient quantity of food. Meals on board ship were served to the crew on a square wooden plate in harbor or at sea in good weather. Food in the Royal Navy was invariably better or at least in greater quantity than that available to the average landsman. However, while square wooden plates were indeed used on board ship, there is no established link between them and this particular term. The OED gives the earliest reference from the U.S. in the mid 19th century.
- Stern - The rear part of a ship, technically defined as the area built up over the sternpost, extending upwards from the counter to the taffrail.
- Surge - A vessel's transient motion in a fore and aft direction
- Sway - A vessel's motion from side to side.
- Three sheets to the wind - On a three-masted ship, having the sheets of the three lower courses loose will result in the ship meandering aimlessly downwind. Also, a sailor who has drunk strong spirits beyond his capacity.
- Touch and go - The bottom of the ship touching the bottom, but not grounding.
- Traffic Separation Scheme - Shipping corridors marked by buoys which separate incoming from outgoing vessels. Improperly called Sea Lanes.
- Underway - A vessel that is not at anchor, or made fast to the shore, or aground.

Nautical Terms

- **Weigh anchor - To heave up (an anchor) preparatory to sailing.**
- **White Horses – Waves in wind strong enough to produce foam or spray on the wave tops.**
- **Wide berth - To leave room between two ships moored (berthed) to allow space for maneuver.**
- **Windage - Wind resistance of the boat.**
- **Windward - In the direction that the wind is coming from.**
- **Yaw - A vessel's motion rotating about the vertical axis, so the bow yaws from side to side.**

Contact Information

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  - Dennis.W.Webb@usace.army.mil
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- **Note: COE offers a PROSPECT course**
  - Design and Maintenance of Deep-Draft Navigation Channels
    - Has not been offered in a number of years.